Physics Notes

Name: Date:

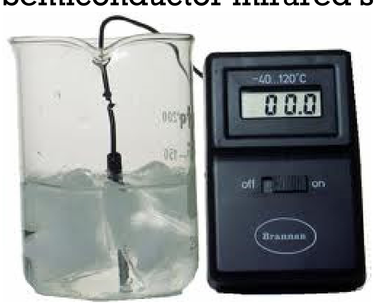
***Chapter 21**: Temperature, Heat, and Expansion*

1. It can be generally stated that **all matter is in constant motion**. You may recall that the energy of motion is referred to as kinetic energy (KE).

2. The terms "warm" and "cold" are very subjective – depending on the observer. More specifically, **the matter of warm objects has a greater amount of average kinetic energy than cold objects**.

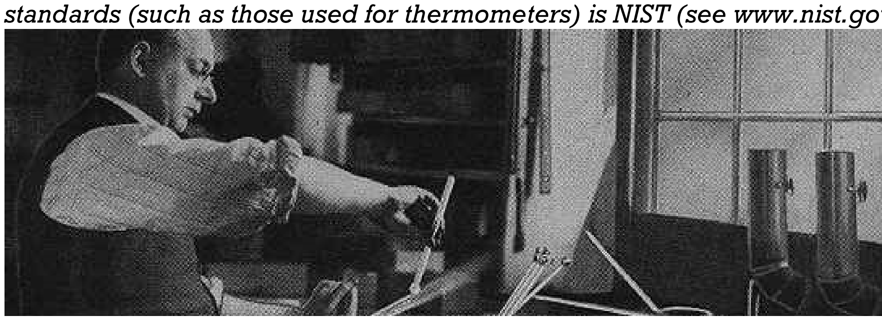
3. **Temperature** is a way of quantifying heat energy compared to a standard.

4. **Thermometers** are man-made devices that can measure temperature using:
    a. Expansion / Contraction of liquid in a small capillary tube (*contact*).
    b. Semiconductor infrared sensors (*non-contact*).



A Digital Thermometer
Image: cs.iupui.edu

Thermometers are calibrated according to a set standard. These set standards were not established until the 19^{th}-20^{th} centuries. *The U.S. government department responsible for calibration standards (such as those used for thermometers) is NIST (see www.nist.gov).*



Filling an Hg Thermometer / Image: http://www.stanford.edu/class/me220

5. There are **3 common temperature scales**:

   a. Celsius: °**C**
   Developed with 100 graduations between freezing/boiling points of water as a reference substance. Also known as centigrade scale.

   b. Fahrenheit: °**F**
   Developed with ~180 graduations between freezing/boiling points of water. This scale has more fine graduations than the other two, and is only used in the USA and a few other countries.

   c. Kelvin: **K**
   This scale is used widely in the scientific community. There are no negative numbers on the Kelvin scale. Absolute Zero (0 K) is the lowest theoretical temperature. The freezing point of water on the Kelvin scale is 273.15 K, while the boiling point is 373.15 K.

Temperature Scales

Fahrenheit	Celsius	Kelvin	
212	100	373	Boiling point of water at sea-level
194	90	363	
176	80	353	
158	70	343	
140	60	333	
122	50	323	
104	40	313	
86	30	303	
68	20	293	Average room temperature
50	10	283	
32	0	273	Melting (freezing) point of ice (water) at sea-level
14	-10	263	
-4	-20	253	
-22	-30	243	
-40	-40	233	
-58	-50	223	
-76	-60	213	
-94	-70	203	
-112	-80	193	
-130	-90	183	-89°C (-129 °F) Lowest recorded temperature. Vostok, Antarctica July, 1983
-148	-100	173	

Reference: Ahrens (1994)
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6. **Absolute Zero** (0 K) is the theoretical temperature at which all motion of matter would cease. *KNOW this temperature in* °**C**.

7. Heat is the common term to describe the energy flow between objects caused by differences in temperature. Our text states "***Heat is energy in transit from a body of higher temperature to one of lower temperature***". (pg. 309)

8. When heat flows between forms of matter, we refer to it as **thermal energy**.

9. Strictly speaking, **matter does not "contain" heat**.

10. When bodies of different temperatures come into contact with each other, energy will flow from the body with greater energy to the body with less energy until both contain an equal amount of energy – a state known as **thermal equilibrium**.

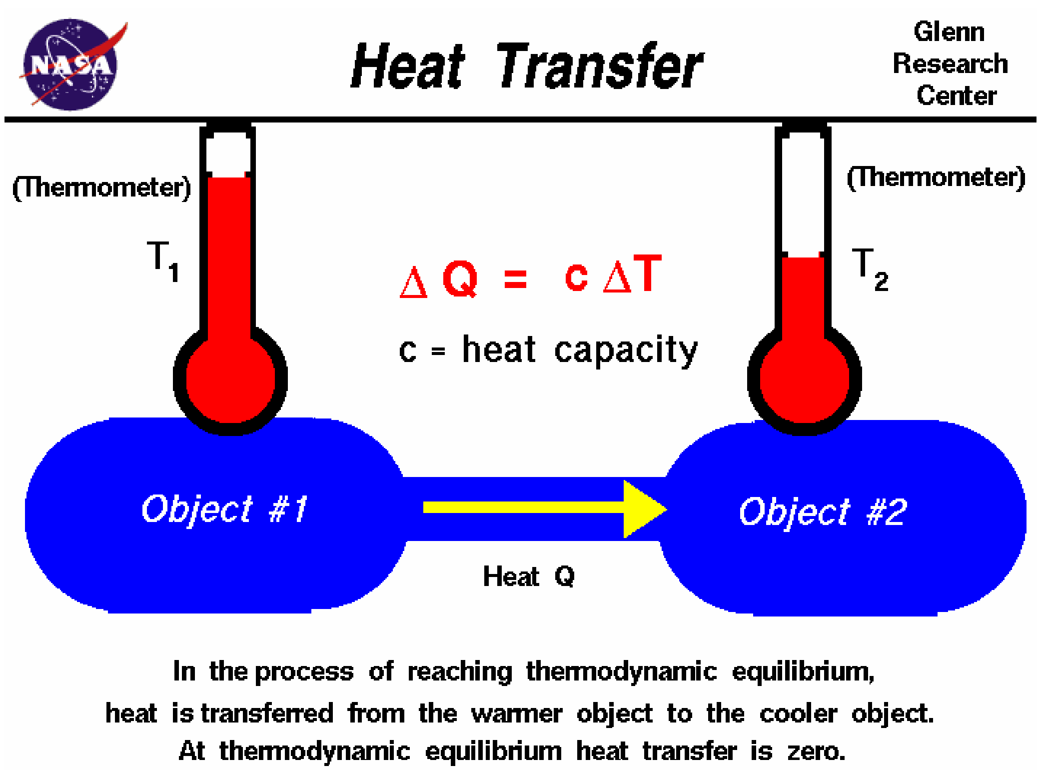
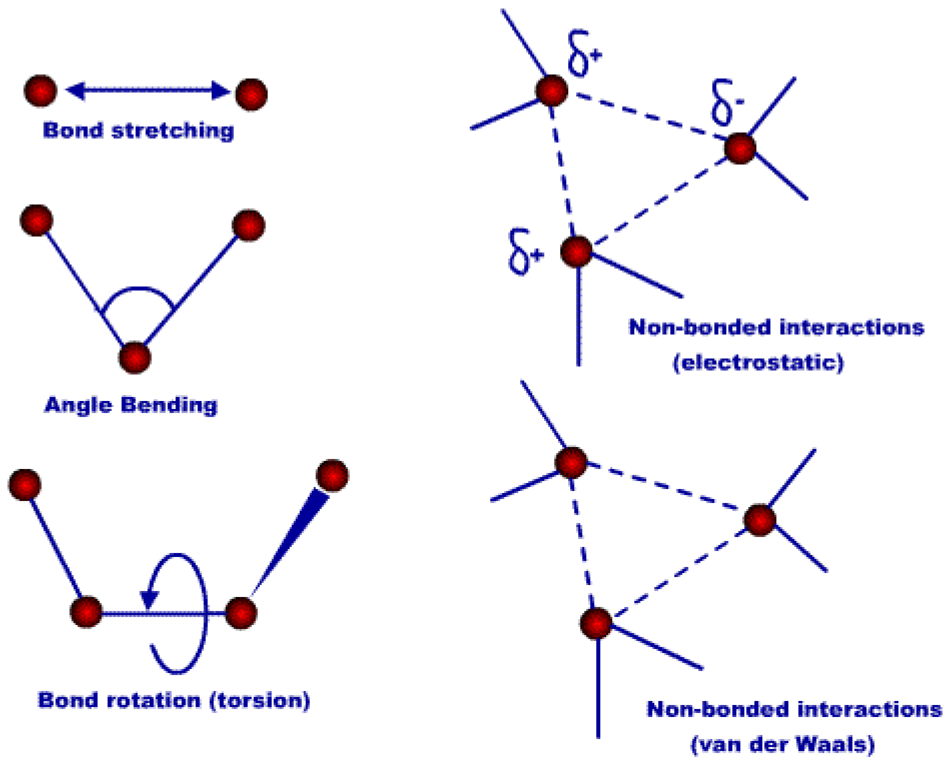


Image: grc.nasa.gov

11. Matter (atoms, ionic compounds, molecules) in motion possesses kinetic energy but *also* possesses **potential energy due to intermolecular attraction forces** (ie. Van der Waals forces…).



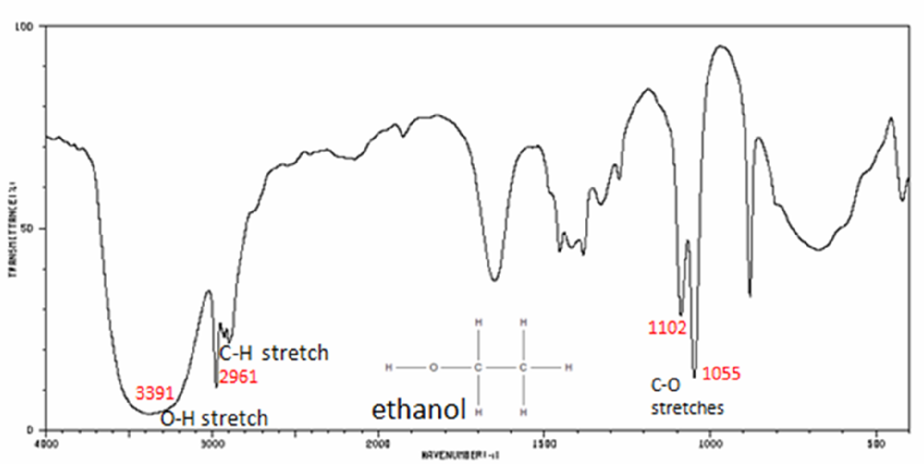
12. Heat energy is measured in discrete quantities known as **calories**. When bodies absorb (receive) heat energy, the temperature of that body will rise. **A calorie is defined as the amount of heat energy required to raise the temperature of 1 gram of water 1°C** (also 1 K). [*NOTE: The actual standard for the calorie is the amount of heat energy needed to raise 1 g water from 14.5°C to 15.5°C.*]

13. On food packaging, you will often see the term "Calorie" (capital "C") used. This "Calorie" is actually a **kilocalorie** (1000 calories) – the amount of heat energy needed raise the temperature of **1 kilogram** by **1°C.**

14. **1 calorie = 4.184 Joules**

15. Another common unit of "heat" is the British Thermal Unit (Btu). **1 Btu is the unit of heat energy required to raise the temperature of 1 pound of water by 1°F.** (~1054 Joules is equivalent to 1 Btu).

16. In most substances, absorbed thermal energy will increase:
    a. **translational kinetic energy** (causing particles to "bounce" off of one another at greater speeds…),
    b. **bond stretching** between atoms within a molecule or lattice structure,



IR Spectroscopy Spectra of Ethanol showing signature bond *stretching* between Oxygen and Hydrogen, Carbon and Hydrogen, and Carbon and Oxygen.
Image: chemwiki.ucdavis.edu

    c. **oscillation kinetic energy** (like an oscillating fan…)

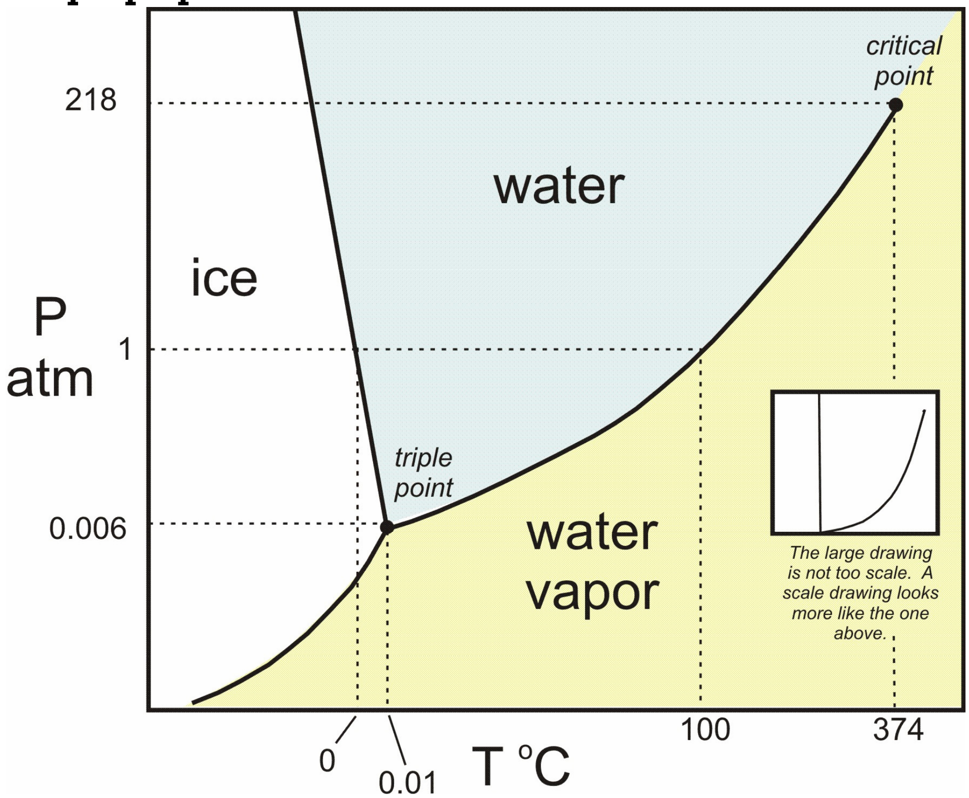
17. **Specific Heat Capacity** is "the quantity of heat required to raise the temperature of a unit mass of a substance by one degree Celsius." (Glossary, pg. 704; also see pg. 314)

Specific Heats of Some Common Substances

Substance	Specific Heat [cal/(g · °C)]
Water (liquid)	1.00
Water (solid)	0.50
Water (gas)	0.47
Ethyl alcohol	0.54
Wood	0.42
Aluminum	0.21
Glass	0.12
Iron	0.11
Copper	0.09
Silver	0.06
Gold	0.03

Table: witcombe.sbc.edu

18. **Unique properties of Water:**



↑ Phase Diagram of Water
Image: serc.carleton.edu

a. Water has a relatively high specific heat capacity, making it resistant to changes in temperature.

b. Water has a specific heat capacity of **1 cal / g °C**

c. A small amount of water can absorb a relatively large amount of heat for a given increase in temperature. This makes water an important cooling agent (ie. *human sweat, automobile coolant, industrial coolant*…)

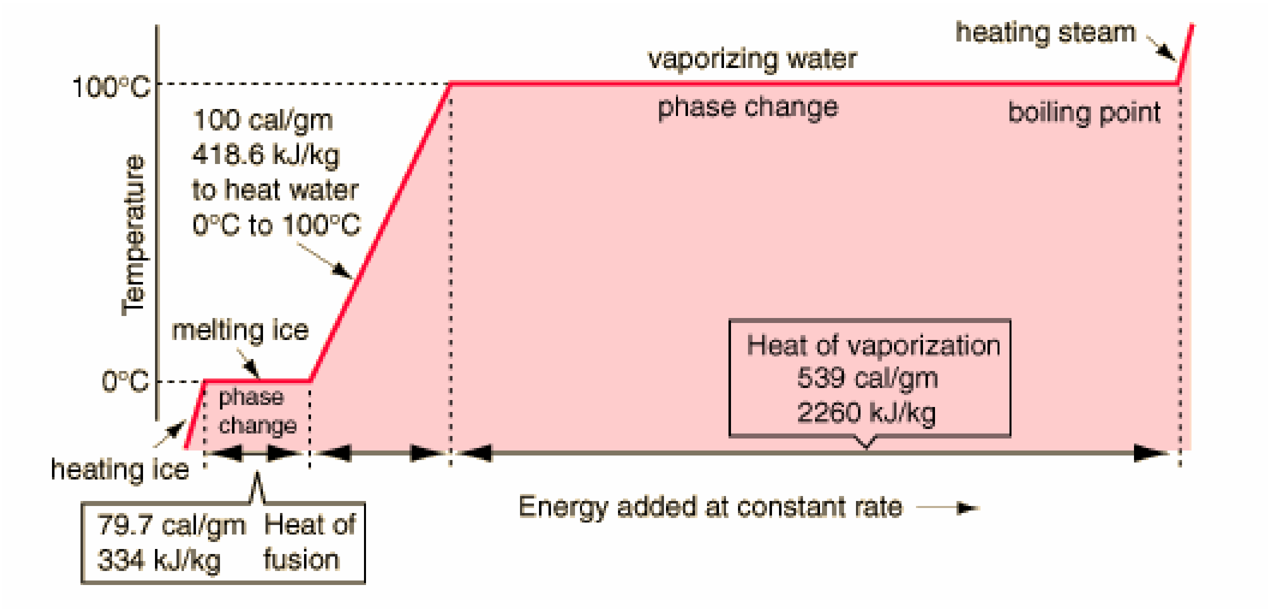
d. Water is at its most dense (as a *liquid*) at **4°C**.
Water expands at temperatures below or above 4°C.
Question: *How might this affect life in a lake during winter*?

e. **Water does not conduct heat well**. Thus, water is considered a thermal insulator.

19. "Heat transfer in calories is given by $\boldsymbol{Q=mc\Delta T}$ where:

m = mass in g c = specific heat capacity

ΔT = change in temperature in °C" (from pg. 323)

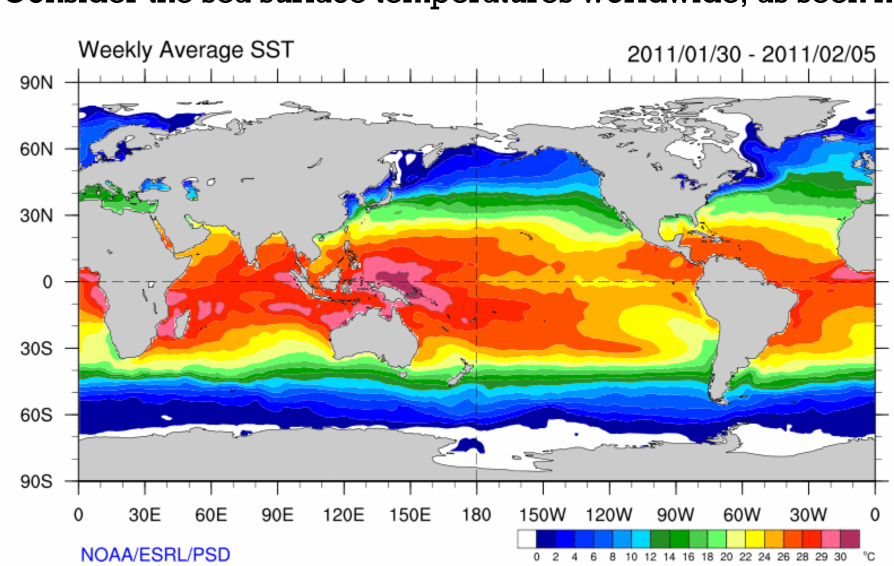


Phase change diagram for water

Image: http://www.physics.louisville.edu/cldavis/phys298/notes/thermeq1.gif

Also Recommended: http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/spht.html

20. Consider the sea surface temperatures worldwide, as seen here:



Water at the equator is hot! How does this trend affect you?